A Submersible Groundwater Pump for Photovoltaics Operation

PREPARED FOR:

Renewable Energy Branch
Energy, Mines and Resources Canada
Ottawa, Canada
DSS Contract File No: 23216-6-6128/01-SZ
15th. July 1987

PREPARED BY:

Dr.P.R.B.Ward PEng
Ward & Associates Ltd.,
3408 West 40th. Avenue
Vancouver, B.C. V6N 3B6
604-688-8271

SCIENTIFIC AUTHORITY:

Mr J.L. McClung PEng
Solar Energy Development Program
Renewable Energy Branch

CITATION

This report is called:

Ward P.R.B., Ward & Associates Ltd. A Submersible Groundwater Pump for Photovoltaics Operation. Report of Contract File # 23216-6-6128/01-SZ. Renewable Energy Branch; Energy, Mines and Resources Canada, Ottawa, Ontario. 1987.

Copies of this report may be obtained through:

Renewable Energy Branch
Energy, Mines and Resources Canada
580 Booth Street
Ottawa, Ontario
K1A 0E4 Tel. (613) 995-9447

OR through:

Interlibrary Loans
CISTI Library
National Research Council
Bldg. M-55, Montreal Road
Ottawa, Ontario
K1A 0S2 Tel. (613) 993-1585

ACKNOWLEDGEMENTS

Dr. William G.Dunford, Department of Electrical Engineering, University of British Columbia provided contributions to many aspects of the project. The work on building the prototype systems and on sealing the motor was carried out in the UBC Engineering workshops. Performance testing of the pump under pressure was carried out in the hyperbaric chamber, School of Kinesiology, Simon Fraser University. Robbins and Myers Canada Ltd. contributed pump rotors and stators for the Prototypes.

This report is distributed for informational purposes only and does not necessarily reflect the views of the Government of Canada nor constitute an endorsement of any commercial product or person. Neither Canada nor its ministers, officers, employees or agents makes any warranty in respect of this report nor assumes any liability arising out of this report.

PREFACE

This is the final report for year 1 of a programme of research and development on a small photovoltaic powered pump. The work is considered significant because it is in a new area, and because improved understanding of how such pumps operate and may be designed is important to industry. The long term goal of introducing solar powered pumps in remote communities in third world countries and in Canada is a sound objective with potential major benefits to mankind. The project was funded by the Renewable Energy Branch of EMR Canada under the Solar Energy Development Program (75%) and by Peter Ward & Associates Ltd. (25%).

ABSTRACT

One of the best pumps for delivering small amounts of flow through a variety of heads is the progressive cavity pump. Presently available versions of this pump for rural water supplies are driven from the surface via a long drive shaft that transmits the power to the pump element. The long drive shaft carries penalties of severe losses of efficiency and difficultly of installation.

A pump consisting of a sealed submersible motor connected to the rotor and stator of a commercially available progressive cavity pump was conceived. Difficulties of 1). sealing the motor in a simple way and 2). connecting the rotary motion of the motor to the eccentric motion of the rotor of the pump were overcome. Two prototypes, one for very small flows (0.2 litres/s) and one for small flows (0.35 litres/s) were developed and tested. Both pumps worked well over a wide range of heads (10m to 40m).

Measured data show that both pumps consume very small amounts of power working at heads of 10 to 15m. The pumps will thus require only a small photovoltaic array at these heads. In addition they are easy to install and the expected frequency of servicing is very low. For these reasons the pumps are expected to provide a very cost competitive choice for domestic water, small market gardening and stock water supplies. Future work remains to be conducted on the PV array to motor interface, and on field trials.

TABLE OF CONTENTS

TITLE PAGE	1
CITATION	2
ACKNOWLEDGEMENTS	3
PREFACE	3
ABSTRACT	4
EXECUTIVE SUMMARY	6
INTRODUCTION	8
OBJECTIVES	9
METHOD	10
Pump Selection and Testing	10
Motor Selection and Sealing	11
RESULTS	12
Efficiency Analysis	12
Prototype 1	13
Prototypes 2 & 2A	13
Prototype 3	14
DISCUSSION	15
Motor Sealing	15
Experimental Error	15
System Performance	15
Mini-system Feasibility	17
Comparison with Surface Driven Progressive Cavity Pump	18
CONCLUSIONS AND RECOMMENDATIONS	18
REFERENCES	20

List of Figures

1. Prototype 1 Design Drawing
2. Prototype 1 Pump, Motor and Jacket
3. Prototype 1 Rotor, Stator & Cylinder
4. Prototype 2 Design Drawing
5. Prototypes 2A & 3 Photograph of System
6. Flow and Efficiency Curves, Prototypes 2A & 3.

List of Tables

1. Preliminary Efficiency Tests, Mono GFL22 Pump
2. Preliminary Efficiency Tests, Moyno 23201 Pump
3. Efficiency Tests, Prototype 1
4. Efficiency Tests, Prototype 2
5. Efficiency Tests, Prototype 2A
6. Efficiency Tests, Prototype 3

EXECUTIVE SUMMARY

Progressive cavity pumps have been widely used for many years in heavy duty applications. Although they have been used for rural water supply applications in many countries, the tradition in North America has been to use these pumps for industrial applications only. The commercial version of the progressive cavity pump sold for groundwater pumping has a long drive shaft which transmits the power from a surface mounted motor (diesel, gas or electric) to the pump element which is below the water table. Progressive cavity pumps perform much better than multi-stage centrifugal pumps in very low flow, medium head applications and are simpler and more robust than jack pumps. The long drive shaft, which runs inside the water delivery pipe and is supported by rubber bobbin bearings at intervals of 5 feet (1.5m), is difficult to install and causes a loss of efficiency because of friction.

A design of progressive cavity pump driven by a submerged DC motor located close to the rotor and stator of the pump was proposed for this project. The main objectives were to find a successful and easy to implement way of sealing the motor and to find a good method of coupling the rotary motion of the motor to the eccentric motion of the pump's rotor.

After some enquiries, two suitable small pump rotors and stators, manufactured by Moyno Inc. and sold in Canada by Robbins & Myers Canada Ltd., were found. These rotors and stators are short and are used for small industrial pumps. The eccentric motion of the pump rotor is taken care of by a special design of rubber stator with an outer sleeve, see Figure 3. This flexible design allows the inner part of the stator to move eccentrically to accomodate the motion of the rotor. The stator is known as a wobble stator. Performance tests were carried out on a pump employing the smaller of the two rotor/stator pairs, known as the Moyno SP232 pump. The pump was driven from a DC motor via a drive belt, and measurements of power supplied to the motor and power developed from the lift and flow of water were made. Efficiency calculations for both the motor and the pump were carried out and tabulated.

Work was carried out on the best procedure for sealing the motor. A system employing a rubber sleeve that sealed the sides and bottom of the motor and a specially machined top cover with a 5/8 inch oil seal for the drive shaft was adopted. The rubber sleeve was made deliberately too long for the pump, so that it collapsed and automatically adjusted the pressure inside the pump to be equal to the outside pressure. The system was tested and photographed while under pressure in a hyperbaric chamber, and was found to work well at heads of up to 15 meters.

Trials of two initial prototypes showed that:

1). the use of a pump rotor rigidly connected to the shaft of the motor was unwise, and produced a pump with low efficiency

2). the way in which the stator was supported was important. Insufficient support would cause the stator to "blow out" , deforming it so badly that the pump would fail at heads of 100 to 200 kPa.

Two prototypes (known as 2A and 3) that worked very well were constructed, one using a rotor/stator pair that produced about twice the flow rate of the other. Both prototypes used a common housing, see Figure 4, that connected the motor drive shaft to the pump rotor via a 70 cm long steel rod which easily flexed the necessary distance (about 3mm) to accomodate the eccentric motion of the pump rotor. The outside of the stators were carefully supported so that they would not blow out under pressure.

Performance tests on the pumps showed that they were efficient and versatile. Good performance over the whole range of pressures 100 to 400 kPa was found, see Figure 6. For Prototype 3, peak efficiencies for the motor-pump system of a very creditable value (43%) were measured. This number is very close to the target efficiency (45%) set for very good pump-motor systems in 1983 (Sir W. Halcrow 1983) for pumps that were significantly larger than Prototype 3. The amount of power required for operation at heads of 100 to 150 kPa was found to be very small (under 100 watts). This is important, because the number of photovoltaic panels required to drive such pumps is small, enabling the cost of the whole system to be modest. The cost would be lower than wind powered pumps and would compete with gasoline motor driven pumps over a period of 2 years or more, because of very much better predicted reliability. This is a significant finding, and suggests that in volume production sales of a pump of this type would do well because of price and reliability advantages.

Research and development work remains to be carried out on the drive system, particularly the interface between the photovoltaic panels and the motor.

INTRODUCTION

Progressive cavity pumps are widely used in North America for heavy duty industrial applications. Examples include pumping of viscous fluids, pumping corrosive liquids such as acid and pumping silt laden water. In addition progressive cavity pumps have been used extensively in Africa and other continents for groundwater pumping. The pumps are powered by grid electricity, diesel and gas motors and by hand. In Zimbabwe, Botswana, Swaziland, Lesotho and Republic of South Africa as much as 60% of the agricultural and rural market is supplied by pumps of this design (information from Mono Puumps Africa Pty Ltd., Johannesburg).

Progressive cavity pumps are a version of the renowned Archimedes screw pump modified for use at high pressures. The results of experiments to determine the speed and torque characteristics of a commercial version of the pump sold for borehole applications have been published, (Ward, Dunford and Pulfrey, 1987). Laboratory experiments with an 800 watt photovoltaic array to determine daily water volumes pumped and performance at heads other than the design head have been made (Pulfrey, Ward and Dunford, 1987). A stainless steel rotor shaped in the form of a helix turns inside a natural rubber stator also shaped as a helix. The rotor moves so that part of the rotor is always in touch with the high point line of the stator, creating a long seal with good characteristics for prevention of backflow. The pump functions over a range of speeds that make it well suited to direct connection to an electric motor with no need for gear reduction.

The good performance of the pump at a variety of speeds is an important aspect for direct operation with solar power. Photovoltaic panels are still expensive and constitute the majority of the cost of the system for most pumps other than very small systems. It is thus important for the pump to be able to operate efficiently and to pump its full design head early and late in the day. Progressive cavity pumps are able to develop the full design head when operating at only 1/3 of maximum design speed. Efficiencies at 1/3 of maximum design speed are about 80% of the values at maximum design speed. These favourable characteristics, together with their robustness are why progressive cavity pumps were selected.

One of the main drawbacks to the presently available progressive cavity well pumps is that a long drive shaft is used. This runs down the inside of the delivery pipe and transmits mechanical power from the surface to the pump element, which is close to the bottom of the well. The drive shaft is supported at intervals of 5 feet by rubber bobbin bearings which prevent the shaft from flexing and hitting the inside of the delivery pipe. These bearings consume

energy; a manufacturer's estimate is that about 70 watts of power is consumed for every 30m of drive shaft required. In addition, the task of installing and servicing the pump is made difficult by the need to remove and install not only the delivery shaft but also the drive shaft. For medium and deep wells a tripod over the well head is needed for installation and servicing.

Work on pump testing, system economics and system sizing has been carried out by the World Bank (Sir William Halcrow and Partners, 1983, 1984). The reports show that for rural water supply, solar pumping applications are becoming cost competitive compared to diesel pumps where the average daily water requirements are less than about 250 m4, and where the monthly average solar radiation is greater than 10 MJ/m2 per day. The units m4 are used as a convenient, abbreviated way of defining pumped water energy (e.g. 10 m3/day through a head of 25m is equivalent to 250m4 per day). The reports emphasise the fact that pumping applications requiring small amounts of energy may be economically serviced by small photovoltaic pumping systems, and that future price reductions in photovoltaic panels will broaden this economic advantage.

OBJECTIVES

The design, construction and testing of a progressive cavity pump driven by a submersible motor is proposed. The pump should be suitable for installation in a standard 6 inch (150mm) diameter well. The use of the submersible motor allows operation without the long drive shaft, with major advantages from the point of view of system efficiency and installation and servicing cost reductions.

The major questions to be resolved in the course of the work are:

1). Finding a reliable and cost effective way of coupling the motion of the motor (axial) to that of the rotor of the progressive cavity pump (rotates and translates through a circle of small diameter).

2). Finding a reliable and cost effective way of sealing the motor against small water heads.

3). Determining whether a small rotor and stator suitable for delivering water under conditions of very small amounts of required power is commercially available.

4). Efficiency testing of the assembled pump systems using laboratory supplied power.

5). Comparison of the submersible pump with results from tests on a surface driven progressive cavity pump.

METHOD

Pump Selection and Testing

Enquiries to the two major progressive pump manufacturers showed that small rotors and stators for delivering water under conditions of very small amounts of required power were available.

Manufacturers' data for the smallest commercially available progressive cavity pumps show that they require about 150 to 250 watts to pump water from heads of about 20m. Two types of pumps from each of two manufacturers were investigated for use in the project. These were:

Mono GFL Solar	(supplied with long coupling)
Mono P32	(supplied with long coupling)
Moyno SP232	(supplied with wobble stator)
Moyno SP333	(supplied with wobble stator)

The first two pumps are down-well type pumps used in water supply applications. A long rod is used to overcome the problem of coupling the axial motion of the motor to the eccentric motion of the pump's rotor.

The second two pumps are small, compact industrial pumps. The coupling problem is overcome by using a special design of pump stator. The stator element is supported by a rubber surrounding jacket which leaves the stator free gyrate slightly around the rotor (known as a "wobble" stator). The pump rotor can be directly aligned with and connected to the motor drive shaft.

The smaller of the two pumps from each manufacturer, i.e. Mono GFL and Moyno SP232, were selected for initial testing.The pumps were set up on the pump test tank, which uses a back-pressure sustaining valve to simulate a variety of different heads. Electrical currents, voltages, water flows and water heads were measured.

Tables 1 and 2 present the results of the tests. The best working point for the Mono GFL pump was at about 20m head and 400 to 1000 rpm where the efficiency was about 50-52%. The best point for the Moyno SP232 pump was at about 20m head and 600 to 1200 rpm, where the efficiency was about 30

to 33%. The Mono GFL pumps about twice the flow compared with the Moyno SP232.

Plans were made to design the initial system around the Moyno SP232 rotor and stator since the prospects existed of achieving a significant improvement in efficiency. In addition, the Moyno SP232 was sufficiently small that it would operate on very few solar panels (only about 100 watts required at head of 20m).

Motor Selection and Sealing

Several DC Permanent Magnet motors, manufactured by Doerr, were sufficiently narrow to fit into a 6 inch (15 cm) well with a good margin of clearance. Sizes in the range 1/2 to 1 HP were available. The pump tests showed that running torque values of 1 to 1.5 Nm would be required at 20m head. The Doerr 3/4 HP Permanent Magnet motor was capable of developing about 3 Nm at maximum current, and this was considered sufficiently in excess of the design torque, that the 3/4 HP motor would be a good selection for the system.

The motor was purchased and some bench tests were carried out to establish the friction and windage losses at a variety of speeds from 200 to 1890 rpm. The line of best fit for these losses was found to be:

$$\text{Power Lost (f and w)} = 0.0041\ N^{1.2}$$

in which N is motor speed in rpm

The armature resistance was measured as 3.70 ohms, and thus the equation for the total power lost in the motor was:

$$\text{Power Lost (total)} = 3.70\ I^2 + 0.0041\ N^{1.2} \quad \ldots\ldots(1)$$

in which I amps is the current supplied.

Several procedures for sealing motors were tested. In one of the methods, both ends of the motor housing were rebuilt, and the shaft was sealed with a very free running teflon seal manufactured by Bal-Seal. The tolerances on this seal were, however, found to be too close for convenient assembly and production.

Finally a method of sealing and pressurising the motor that was simple and easy to manufacture was devised. A natural rubber jacket of cylindrical shape, with one end closed was made, to fit exactly around the outside of the motor. The end of the rubber jacket was sealed against the motor with a hose pipe clamp. This sealed the lower end and sides of the motor. The top end of the motor (which supported the drive shaft) was removed, and a replacement end, carrying a shaft

seal was made. The shaft seal selected was a flexible neoprene "oil" seal, with a steel retaining spring to maintain a small amount of tension against the drive shaft. The seal was sufficiently flexible to allow for small differences in diameter between the shaft sizes of different motors of the same type.

Electrical connector wires were lead out of the top of the motor, and were sealed with silicone to prevent leakage.

Pressure testing was carried out in the hyperbaric chamber at the School of Kinesiology, Simon Fraser University. Tests in the chamber offerred the possibility of monitoring the system as it was pressurised to see how the pressurising rubber sleeve worked. The sealed motor and pump were submerged in about 0.5m of water in the bottom of the chamber.The pressure was raised gradually and held at heads of 12, 20, 30 and 45 ft. (4, 6, 9 and 13.5m). Photographs of the pump were taken through the window of the chamber. At the end of the experiment, the pressure was reduced to atmospheric, the pump taken out of the chamber and the rubber sleeve removed and inspected for water leakage.

Various procedures for coupling the motor to the pump were constructed and performance tested. These are described in the next Section.

RESULTS

Efficiency Analysis

The performance testing was carried out using a tank with a back-pressure sustaining valve to maintain the required heads. Flow rates were measured with a standard water meter and pressures were measured with a good quality pressure gauge. Losses in the motor and the pump were calculated.

The power supplied to the motor was calculated from the product of the input current times the input voltage. The power out of the motor (Pom) was calculated from the input power minus the power lost in the motor (equation 1). This amount of power was assumed to be equal to the power supplied to the pump, since the transmission losses via the direct shaft coupling were very small.

The final power delivered by the pump (Pop) was given by:

$$Pop = gHQ \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

in which = density of water (1000 kg/m3)
g = gravitational acceleration (9.8 m/s2)
H = head in meters
Q = flow rate in m3/s

The efficiency of the pump is:

$$Epump = Pop/Pom \quad \text{.....(3)}$$

Prototype 1

The rotor from the Moyno SP232 pump was attached directly to the motor shaft for this system (known as Prototype 1), see Figure 1 and 2. The stator was supported in a specially made cylindrical housing, as shown in Figure 3. The clearance between the stator and the cylinder walls was made to be sufficiently large to allow the stator to move eccentrically (wobble), but sufficiently small to support the walls of the stator when they were inflated by the pressure developed by the pump's operation.

The pump was connected to the test tank, and a series of measurements made at heads of 0, 4 and 20m. Table 3 documents the results. The efficiency reached by the pump at a head of 20m. was a maximum of 12 to 15%. This was lower than had been expected. Inspection of the condition of the stator after the measurements showed that the stator had been pressing and moving slightly against the inside of the cylinder. The amount of friction developed by this action was probably large, leading to large energy losses and low efficiencies.

A decision was made to arrange the Moyno SP232 rotor and stator so that the rotor was allowed to move eccentrically. This would avoid the power losses associated with energy consuming movements of the stator, and allow the stator to remain relatively stationary. The penalty would be that the revised system would be larger than the compact system of Prototype 1, however, possible gains in efficiency made trials with a new design worthwhile.

Prototypes 2 and 2A

A design with the Moyno SP232 rotor driven by a flexible steel drive rod was conceived, see Figure 4. The design featured the sealed motor, a narrow support cylinder (diameter 8 cm and length 70 cm), a drive rod and a rotor-stator housing with delivery pipe connection. The flexibility of the drive rod was a compromise, it was sufficiently flexible that the rotor could move eccentrically while allowing the stator to stay almost stationary, and it was sufficiently rigid that it did not vibrate against the inside of the support cylinder. The rod diameter selected was 3/8 inch (9.5mm). The housing for the rotor-stator unit was made big enough that it would accomodate both the SP232 and SP333 stators.

461510

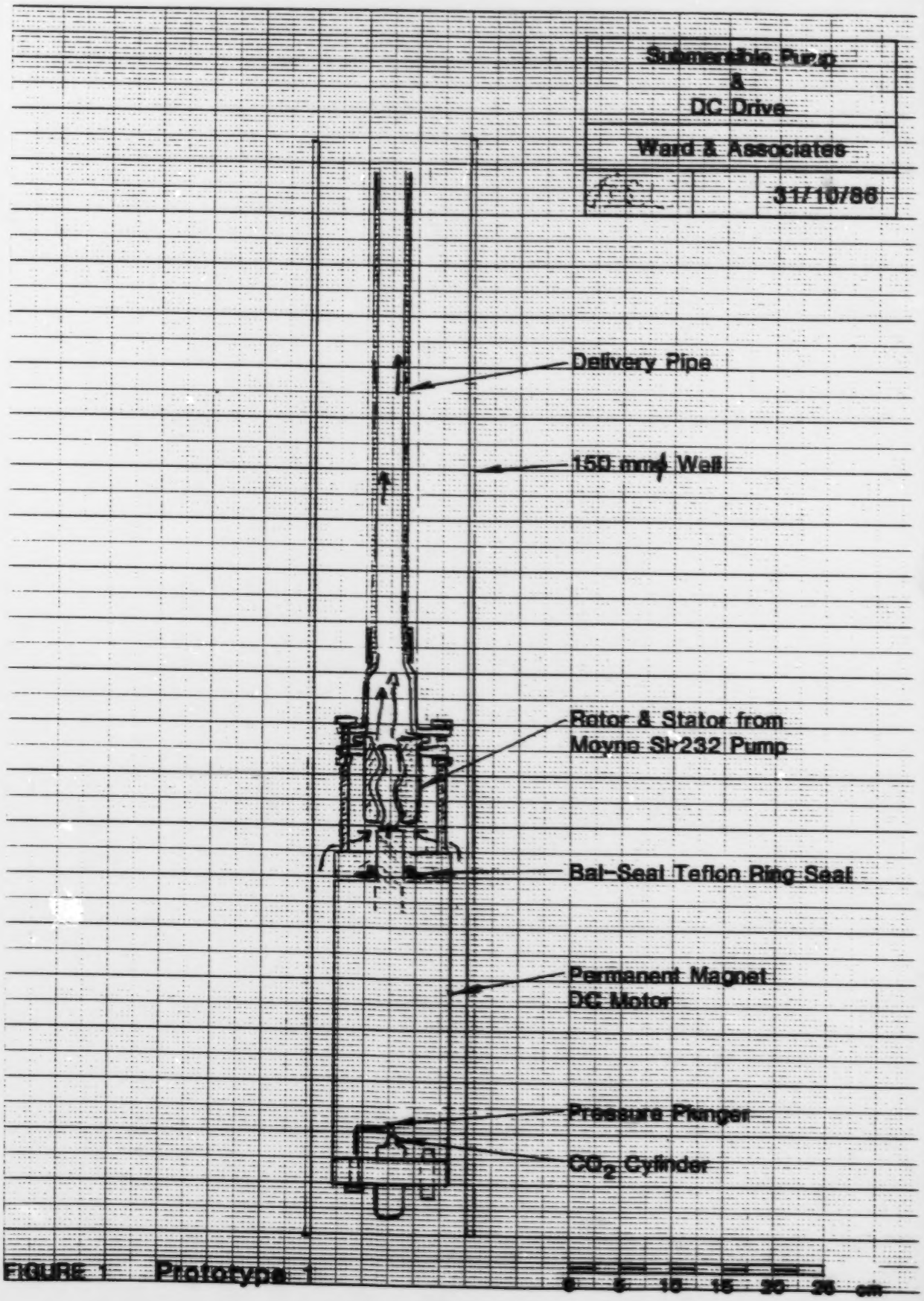


FIGURE 1 Prototype 1

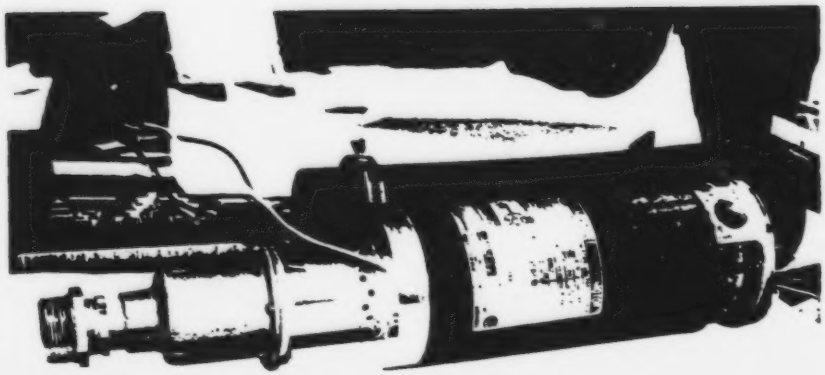


FIGURE 2 – Prototype 1 Pump, Motor & Jacket

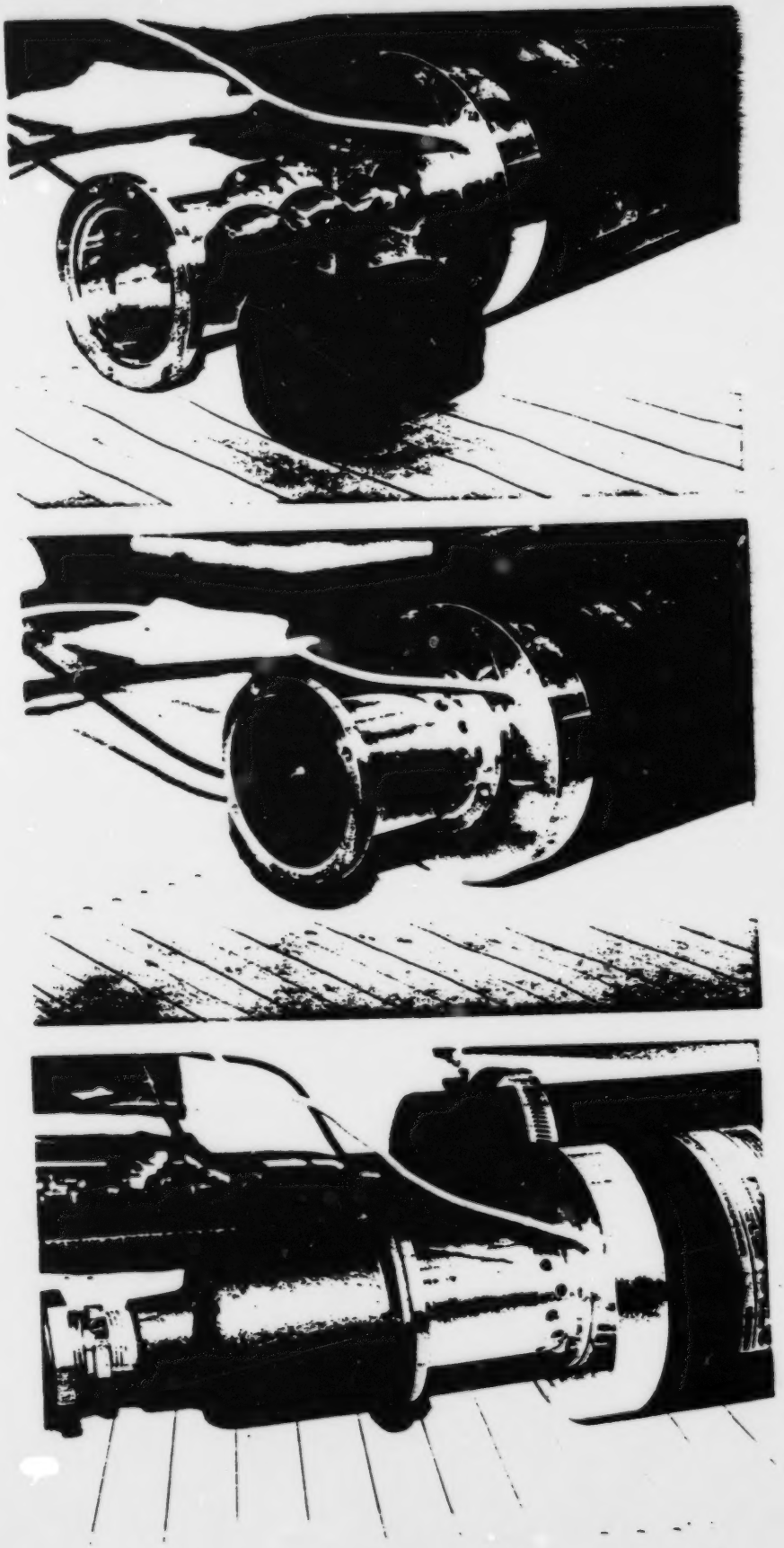


FIGURE 3 **Prototype 1 – Rotor, Stator & Cylinder**

40 1512

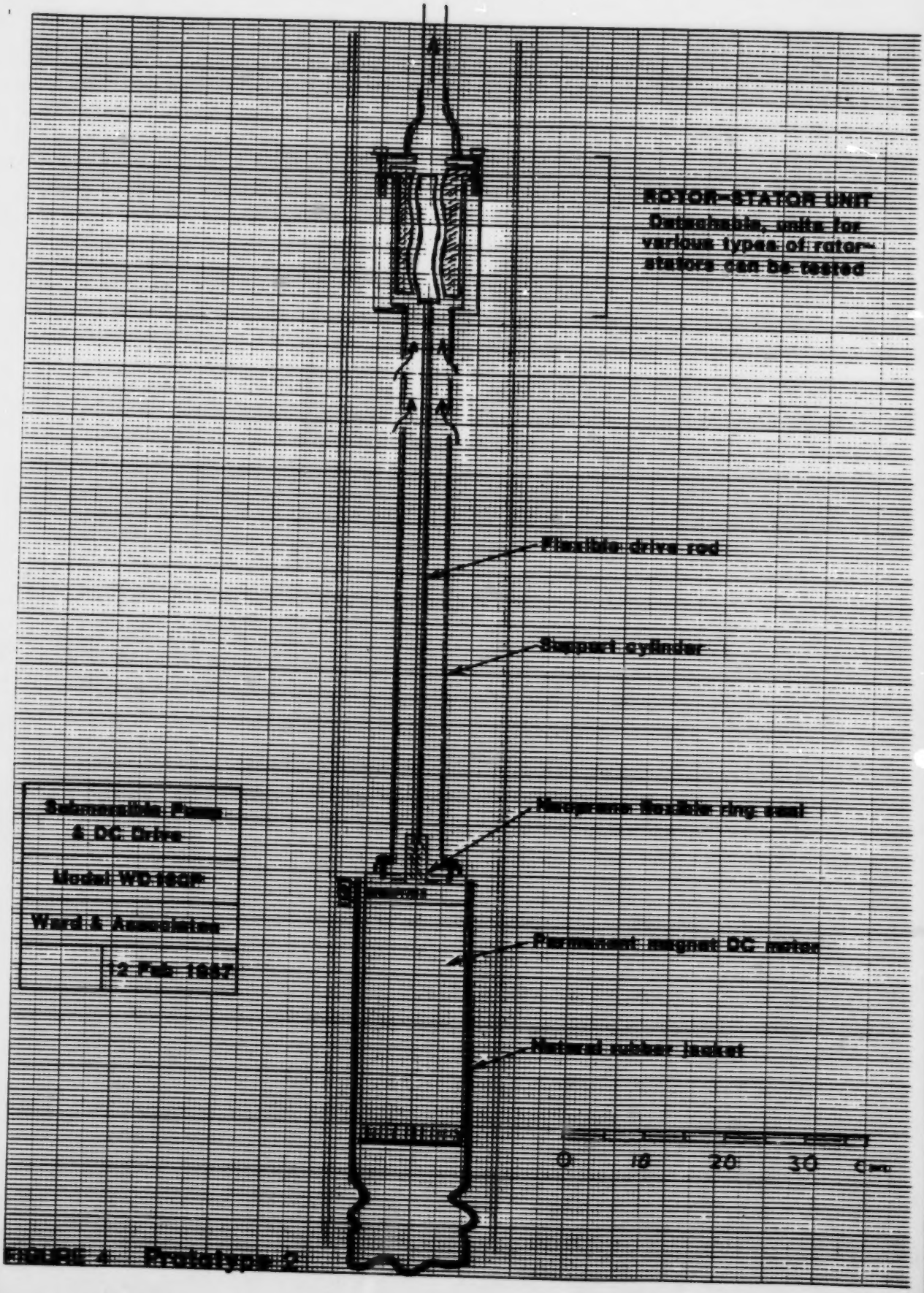


FIGURE 4 Prototype 2

A series of tests was run, starting at a pressure of 55 kPa at a variety of speeds. At pressures above 100 kPa, the pump failed to work. Careful inspection of the pump stator showed that this was due to the rubber stator ballooning under pressure, causing the inside of the stator to lift off the rotor. The stator was then strapped with fibre reinforced tape to prevent ballooning and the tests were resumed. Measurements at heads in the range 55 to 200 kPa were carried out (see Table 4). At heads in excess of 250 kPa the pump failed to work, and inspection of the system showed that the fibre reinforced tape had broken due to the pressure.

The stator cavity was then modified to allow for the use of the tapered housing suppplied by the manufacturer to support the stator. The clearance between the outside of the stator and the inside of the manufacturer's housing was about 4mm. This was sufficiently little that it offered good support to the stator when under pressure and prevented it from ballooning. This version of the prototype was known as Prototype 2A. The pump was connected to the test line and a successful series of tests was run over a very wide range of heads (100 to 500 kPa, see Table 5).

Trials were made with straightener vanes to remove circulation from the flow at the exit of the Prototype 2A pump. Pump efficiencies were measured over the range 100 to 500 kPa.

Prototype 3

The same outer housing and flexible drive rod used for the Prototypes 2 and 2A pump were used. A rotor and stator suitable for the same range of heads but about twice the flow as the Prototype 2 pumps were selected. These were the Moyno SP333 rotor and stator. The task of supporting the tapered stator of the Moyno SP333 pump was carefully assessed and it was decided that this would be best accomplished by filling the space between the stator and the outer cylindrical housing of the pump with plaster of paris. This procedure was tried and found to provide satisfactory support for the stator and allowed the pump to work well. Production versions of the pump will use Portland cement or other material that is cast and sets hard as a filler. Efficiency tests were successfully carried out over the range 100 to 500 kPa and at speeds up to 1750 rpm, see Table 6. At the highest head and speed, the motor was still well within its rated power capacity.

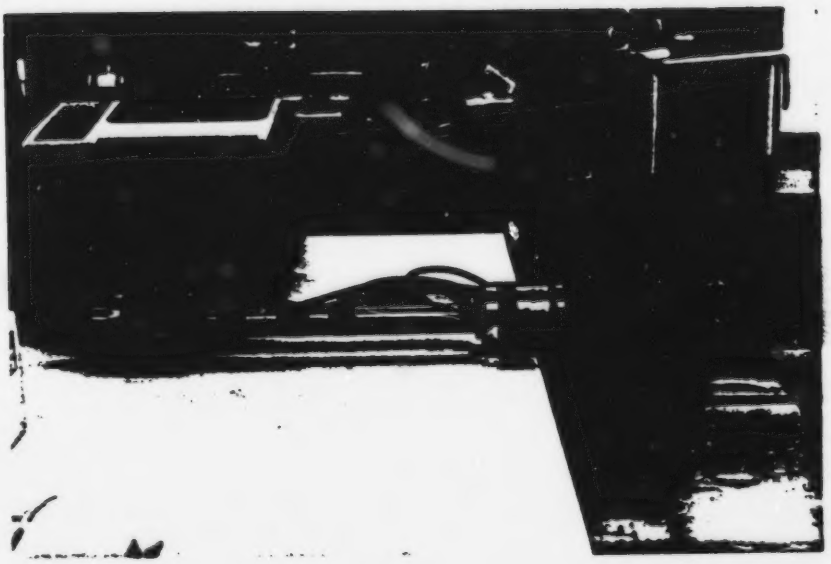
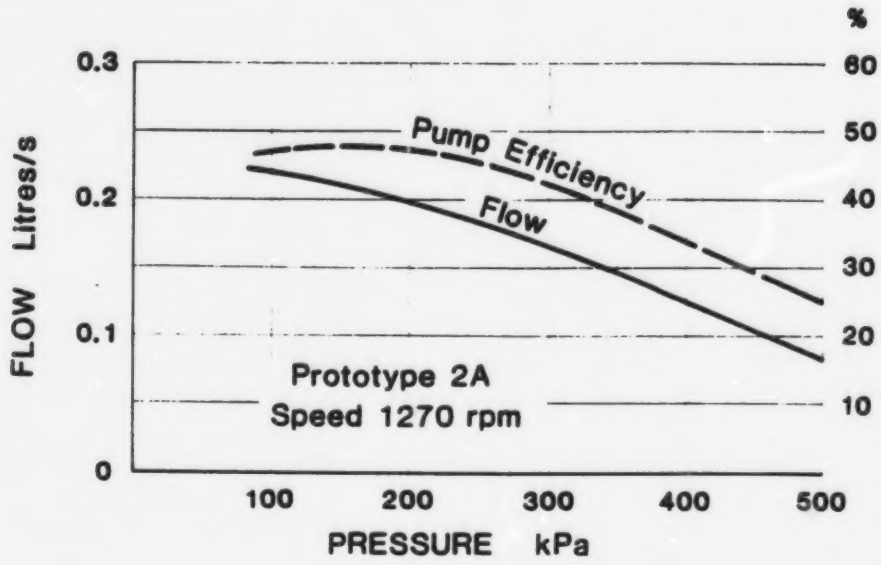


Figure 5. Motor and Pump Housing for Prototypes 2A and 3.



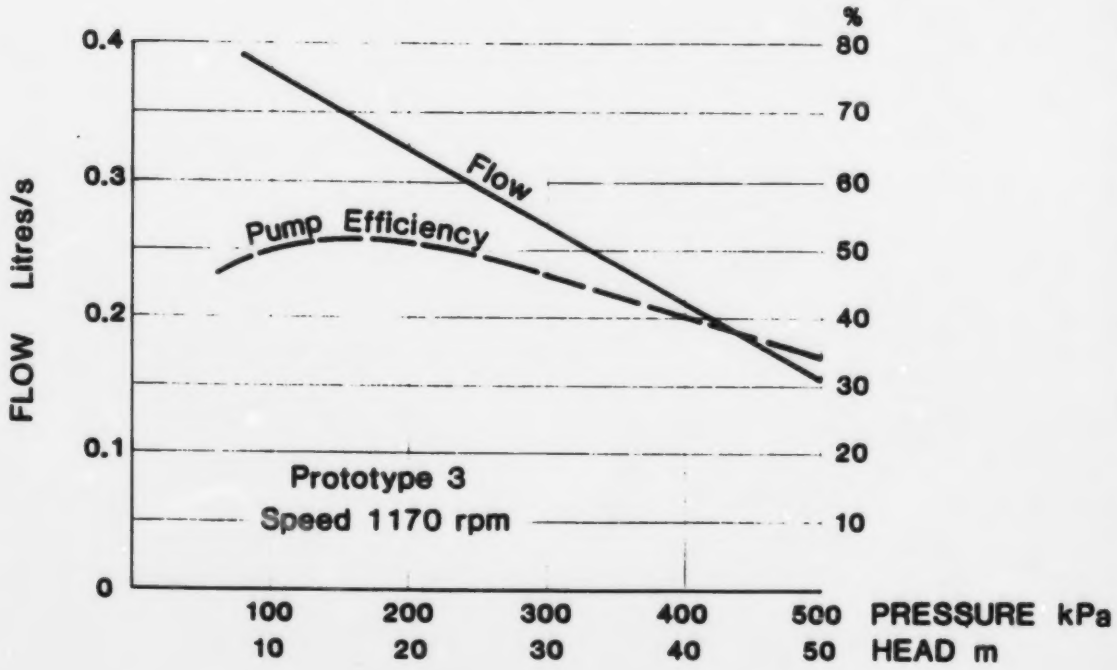


FIGURE 6. Flow and Efficiency Curves, Prototypes 2A & 3.

DISCUSSION

Motor Sealing

The method of sealing with the rubber jacket was observed to work well. The observations made in the hyperbaric chamber showed that the jacket was continuing to compress, even at heads of 13.5m. In practice the difference in head between the water surface level in the well and the elevation of the pump-motor should be considerably less than this.

The jacket was observed to sandwich and to develop two lobes, one on each side, when under pressure. This would be unsatisfactory in practice in a well, because the jacket would foul against the inside of the well and would become jammed. In production versions of the pump the jacket should be surrounded by an open mesh steel cage, which would still allow the jacket to collapse under pressure but would prevent it from developing the protruding lobes.

Experimental Error

The pressure gauge was calibrated with an Ashcroft type 13005 gauge tester. Over the range 100 to 500 kPa the readings were found to be within 2.0% of the correct result. The mechanical flow meter was calibrated by weighing the water delivered and multiplying by the density. The flow meter was found to be accurate to within 2% of the true volume. At low flow rates (less than 0.04 l/s), errors of flow measurement of about 4% were incurred, however this affected a small proportion of the results. Readings of amps and volts taken from the multimeter were assumed to be accurate to within 1% of the correct result. The error in fitting the friction and windage loss data to the power relationship (equation 1) was 2%.

A value of about 2.5% may be used as a total error on the motor efficiency values (e.g. tabulated efficiency value of 0.81 may be in the range 0.79 to 0.83). For the pump efficiency values, a value of about 4% may be used for the majority of values except those taken at the lowest flow rates (e.g. tabulated efficiency value of 0.50 may be in the range 0.48 to 0.52).

System Performance

Prototypes 1 and 2 did not work well enough to be useful because of low efficiencies (Prototype 1) and failure under pressure (Prototype 2).

Prototype 2A, which employed the flexible drive shaft and the small Moyno rotor and stator worked very well with pump efficiencies that are high for very small pumps. For example at about 1270 rpm and 100 kPa pressure, Prototype 2A was 31% efficient overall and the pump alone was 47% efficient (see Table 5). At this speed the whole system drew only about 70 watts of input power. Comparison with tests on the original pump supplied by the manufacturer and driven by a DC motor via a drive belt (see Table 2) show that the pump efficiency has been very much improved (only 26% pump efficiency at 1200 rpm and 100 kPa head with the original pump.

The main reason for this improvement is that the original pump is fitted with a rigidly connected rotor and relies on movement of the stator to accomodate the required eccentric motion of the rotor in the stator. This is an energy consuming action, and a significant amount of energy is lost in flexing the stator to and fro. In comparison, the Prototype 2A system allows the stator to remain stationary, and relies on flexing of the steel drive shaft to provide the eccentric motion of the rotor. Because the shaft is relatively long and thin, this flexing occurs easily and consumes very little power.

Prototype 2A also showed that it was very versatile. Acceptable efficiencies were measured at heads over the whole range 100 to 400 kPa, see Figure 6, and over a wide range of speeds. Satisfactory operation from 400 rpm to maximum speed (1800 rpm) is possible at 100 kPa and from 900 rpm to maximum speed at 400 kPa.

The use of straightener vanes to remove circulation from the flow (Prototype 2B) resulted in no improvement in pump efficiency and is therefore not recommended. For small flow rates, Prototype 2A is thus the system of choice.

Prototype 3, using the Moyno SP333 rotor and stator and flexible steel drive shaft also worked very well. It has about double the flow capacity of Prototype 2A. At 100 kPa pressure and 1170 rpm the pump is 50% efficient and the pump-motor system is 39% efficient (see Table 6). The flow rate at this speed is 0.39 l/s, sufficient to supply a herd of 185 head of cattle with drinking water on a sunny day. The peak power required for this condition is 95 watts, and this could be met with only about 2 to 3 solar panels in good sunshine. At 200 kPa head and the same speed, the pump and total system efficiencies are also very good (52% and 43% respectively). The prototype 3 system is versatile and performs well over the whole range 100 to 500 kPa, see Figure 6. The SP 333 rotor and stator make better use of the power available from the Doerr 3/4 HP motor than does the smaller SP232 rotor and stator used in Prototype 2A. Thus the motor efficiencies in the Prototype 3 results are higher than those in the Prototype 2A results.

The highest motor-pump subsystem efficiencies measured for Prototype 3 are very close to the target efficiency for the motor-pump subsystem of 45% referred to in the World Bank report (Halcrow, 1983). Systems that would provide about $600m^4$ of delivered water energy per day for village water supplies were studied in the report and the target efficiency projections were based on those studies. The Prototype 3 system is very much smaller than the systems tested by Halcrow and is suitable for long term average delivery of about $100m^4$.

The high value for the combined motor-pump efficiency is a major achievement in view of the fact that Prototype 3 is:

(1). significantly smaller than systems considered in the Halcrow report, (it is more difficult to build and operate an efficient small pump than an efficient large pump),
(2). easy to install and service and
(3) able to work well over a very wide range of heads.

The same remarks apply to Prototype 2A.

Mini-System Feasibility

One of the objectives of the work was to determine whether a good system operated by very small amounts of required power was feasible and whether field conditions dictated a need for such a pump.

The fact that the Moyno SP232 rotor and stator were available and could be developed into a very small efficient submersible pump (Prototype 2A) answered the first part of this objective. Enquiries were made from the Groundwater Section of BC Ministry of Environment, Indian and Northern Affairs and from other contacts to determine situations where a shallow groundwater table existed and where grid power was not available. It was established that very good possibilities existed for setting up very low energy consumption pumps, using shallow water tables. Example sites were 1). Gulf Islands, involving use of shallow well water for drinking and small scale vegetable gardening, 2). Nemiah Valley Indian Reserve, near Chilco Lake, involving supply of household water from dug out wells and 3). Cattle water for ranching at sites where lack of water presently limits grazing potential. A preliminary cost comparison showed that either the Prototype 2A or Prototype 3 solar system with a small array could supply water at very much less cost than a windmill, and that the solar systems would have the major advantage of being readily moved from one well to another.

Comparison with Surface Driven Progressive Cavity Pump

For pumping in wells the commercially available progressive cavity pump is driven by a long drive rod running the depth of the well. No data are available for the performance of progressive cavity pumps installed in deep wells. Rough numbers for losses from mechanical friction developed at the bobbin bearings supporting the drive shaft are available, and a guideline of 70 watts of power lost for each 30m length of drive rod has been offered by Mono Pumps Ltd. On this basis the performance of the Prototype 2A and Prototype 3 systems is excellent, because the majority of the power would be lost to the drive shaft if these pumps were used in a surface driven mode.

A comparison was made (Ward, Dunford and Brown 1987) with a system that was field tested at the Ministry of Agriculture range demonstration site at Cache Creek, B.C. where a Mono progressive cavity pump was installed in a shallow well (2m deep). The rotor and stator for the Mono Groundwater Pump are about 3 times longer than the short rotors and stators used in Prototypes 2A and 3. The Mono pump was driven from a 10 panel PV array and DC-DC Converter by a surface mounted DC motor that was directly connected to the pump via a direct (Wood's Sure-flex) coupling. The peak (midday) efficiencies for the pump and combined pump-motor were 54% and 46% respectively at 430 kPa and 960 rpm. The majority of the head was above surface and this system did not establish what the pump efficiency would be in a deep well.

CONCLUSION AND RECOMMENDATIONS

The overall objectives of the program have been met.

Two efficient and and easy to install pumps, known as Prototypes 2A and 3 have been assembled and laboratory tested. A method of sealing the pump motor that will be inexpensive to use in commercial production has been developed and shown to work successfully. In addition a method of linking the motor to the rotor of the pump to accomodate the eccentric motion of the rotor has been developed and shown to be efficient and reliable. Prototype 3 is a small pump suitable for small to medium heads and prototype 2A is a very small pump suitable for small to medium heads. Both pumps are in a size range that make them attractive for photovoltaic powered drives at remote sites. At small heads (10 to 20m) the pumps require only a modest investment in photovoltaic panels and the whole system will compete very well in price with wind powered operations.

For example the Dempster windmill with a 6ft. (1.83m) diameter rotor produces about 43 watts of final water power

over heads in the range 10-20m with 15mph (6.7 m/s) winds. The cost of the system including a small (7m high) tower is about $5000. The anticipated costs of the pump, motor and batteries/converter for the Prototype 3 system are $1500 to $2000. Photovoltaic panel cost for 3 x 47 watt panels is $1700 (assuming $12 per peak watt), plus an additional cost of $100 for the panel support frame. An approximate cost for the photovoltaic powered pump is thus $3300 to $3800. The anticipated servicing costs of the photovoltaic powered system are about the same as that for a windmill, with additional battery replacement costs every 5 years if battery operation is used.

Cost comparisons with diesel are unwise, because diesel systems typically are 2 kW or larger and cater for significantly larger pumping requirements. The cost of the smallest diesel powered pumping system is about $3000. Pumps operated by small, gasoline motors are available, however the interval between major services (about 600 hours) is so short that the high operating and maintenance costs over the lifetime of the system is a major disadvantage.

Further work now needs to be carried out on the drive system for the prototype pumps. The pros and cons of battery operation versus direct operation through a DC-DC converter need to be investigated. This investigation should be carried out with the object of minimising the cost of the whole system, including the cost of the water storage tanks. A good quality DC-DC converter suitable for efficient operation under small power conditions needs to be designed, built and tested under laboratory and field conditions. This converter could be a similar but smaller version of the Wardun WD700 constant voltage tracking converter used to drive the Mono pump system at the BC Ministry of Agriculture range demonstration site. The converter efficiency should be high (greater than 90% efficient) and the switching frequency should also be high (greater than 20 kHz) to minimise the motor losses.

REFERENCES

Halcrow, Sir William and Partners. "Small-scale Solar-Powered Pumping Systems: The Technology, its Economics and Advancement". UNDP Project No. GLO/80/003 executed by the World Bank. Main Report. 1983.

Halcrow, Sir William and Partners. "Handbook on Solar Water Pumping",UNDP Project GLO/80/003 executed by the World Bank, 123p., 1984.

Pulfrey D.L., P.R.B.Ward and W.G.Dunford. "A Photovoltaic-Powered System for Medium Head Pumping". Solar Energy, 38, 4, pp.255-265, 1987.

Ward P.R.B. and W.G.Dunford. "Solar Powered Pumping for Medium Heads". Challenges in African Hydrology (Proceedings of the Harare Symposium), IAHS Publication No. 144, pp. 249-258, 1984.

Ward P.R.B., W.G.Dunford and D.L.Pulfrey. "Performance of Small Progressive Cavity Pumps with Solar Power". Proc. Canadian Journal for Civil Engineering, 14, pp. 284 -287, 1987.

Ward P.R.B., W.G.Dunford and L.G.Brown. "Field Trials of Photovoltaic Powered Progressive Cavity Pump". Accepted for Publication, ASES-CESCI Conference, Portland, Oregon, July 1987.

PRELIMINARY EFFICIENCY TESTS
MOTOR - BROT 1.1 kw D.C. MOTOR SUPPLIED BY MAINS POWER
PUMP - MOYNO MODEL 23201 PROGRESSIVE CAVITY TYPE PUMP

TABLE 1

VARIED RPM AND PUMP HEADS [WATER TEMP 22.5 deg]

PUMP SPEED [RPM]	CURRENT [AMPS]	VOLTAGE [VOLTS]	INPUT POWER [WATTS]	MOTOR TORQUE [NM]	MOTOR EFF.	PRESS. HEAD [KPA]	FLOW RATE LITRE/S	PUMP EFF.
300	NA	NA	NA	NA	NA	100	NA	NA
600	0.88	52.4	46	0.58	0.79	100	0.106	0.29
900	0.90	77.7	70	0.60	0.80	100	0.153	0.27
1200	0.92	103.1	95	0.61	0.81	100	0.196	0.26
1500	0.94	128.3	121	0.63	0.81	100	0.230	0.23
1700	0.98	145.0	142	0.66	0.82	100	0.257	0.22
300	NA	NA	NA	NA	NA	200	NA	NA
600	1.30	52.9	69	0.90	0.82	200	0.093	0.33
900	1.27	78.5	100	0.88	0.83	200	0.136	0.33
1200	1.30	104.2	135	0.90	0.83	200	0.175	0.31
1500	1.32	128.8	170	0.91	0.84	200	0.207	0.29
1700	1.33	145.3	193	0.92	0.85	200	0.227	0.28
300	NA	NA	NA	NA	NA	300	NA	NA
600	NA	NA	NA	NA	NA	300	NA	NA
900	NA	NA	NA	NA	NA	300	NA	NA
1200	1.69	104.8	177	1.19	0.85	300	0.123	0.25
1500	1.70	129.1	219	1.20	0.86	300	0.143	0.23
1700	1.75	145.9	255	1.24	0.86	300	0.154	0.21
300	NA	NA	NA	NA	NA	400	NA	NA
600	NA	NA	NA	NA	NA	400	NA	NA
900	NA	NA	NA	NA	NA	400	NA	NA
1200	2.08	105.5	219	1.49	0.85	400	0.100	0.21
1500	2.12	130.6	277	1.52	0.86	400	0.118	0.20
1700	2.15	147.6	317	1.54	0.86	400	0.129	0.19
300	NA	NA	NA	NA	NA	500	NA	NA
600	NA	NA	NA	NA	NA	500	NA	NA
900	NA	NA	NA	NA	NA	500	NA	NA
1200	NA	NA	NA	NA	NA	500	NA	NA
1500	2.59	133.4	346	1.87	0.85	500	0.095	0.16
1700	2.66	148.5	395	1.93	0.87	500	0.106	0.15

/0[illegible]

TABLE 2

Preliminary Tests with Pump driven by Brot 1.1kW DC Motor supplied by mains power.
Mono GFL22 Pump with 2m of drive shaft and delivery pipe.

Water temperature 20C.
Test Series GFL02

Pump Speed rpm	Mass gm	Input Torque Motor Nm	Power Pump & Belt watts	Pump only watts	Output Head kPa	Power Flow rate l/sec	Power watts	Efficiencie Pump & Belt	Pu alc
203	300	1.15	24	18	95	0.032	3	0.12	0.
397	300	1.15	48	35	100	0.115	12	0.24	0.
800	280	1.07	90	64	100	0.282	28	0.31	0.
996	280	1.07	112	80	100	0.380	38	0.34	0.
1204	380	1.45	183	145	102	0.452	46	0.25	0.
1597	480	1.83	307	256	102	0.645	66	0.21	0.
254	420	1.61	43	35	202	0.078	16	0.37	0.
403	400	1.53	65	52	202	0.124	25	0.39	0.
796	400	1.53	127	102	202	0.300	61	0.48	0.
1006	430	1.64	173	141	206	0.350	72	0.42	0.
1207	480	1.83	232	193	206	0.432	89	0.38	0.
1610	600	2.29	387	335	200	0.580	116	0.30	0.
0	800	3.06			350				
247	570	2.18	56	48	353	0.047	17	0.29	0.
404	570	2.18	92	79	350	0.118	41	0.45	0.
798	590	2.25	188	163	352	0.238	84	0.44	0.
1005	600	2.29	241	209	352	0.296	104	0.43	0.
1205	680	2.60	328	289	343	0.350	120	0.37	0.
1611	780	2.98	503	451	350	0.471	165	0.33	0.

TABLE 3

Submersible Pump Laboratory Trials

Derr DC Motor, 3/4 HP, max 180 volts, max 1750 rpm
Power lost = 3.70 I^2 + 0.0041(n)**1.2
in which I amps is current, n rpm is motor speed
Dyno Model 23201 rotor and stator, with very short coupling

Tests of 31 Jan 1987

INPUT POWER			MOTOR		WATER POWER			EFFICIENCIES		
Volts	Current amps	Power watts	Speed rpm	Power from Motor watts	Press. kPa	Flow l/sec	Power from Pump watts	Motor	Pump	Motc F
3	0.27	0.8	29	0.3	0					
7	0.30	2.1	68	1.1	0					
24	0.40	9.8	237	6.3	0					
40	0.47	19.0	393	12.9	0					
60	0.51	30.3	578	20.9	0					
82	0.51	41.6	792	28.3	0					
101	0.49	49.3	979	32.5	0					
120	0.47	56.4	1167	35.9	0					
141	0.47	66.3	1371	41.6	0					
161	0.47	75.7	1565	46.9	0					
181	0.48	86.9	1760	53.9	0					
50	0.97	48.5	486	38.2	40	0.05	2.0	0.79	0.05	0
91	0.83	75.5	885	58.9	40	0.14	5.6	0.78	0.10	0
133	0.71	94.4	1293	70.3	40	0.25	10.0	0.74	0.14	0
162	0.71	115.0	1575	85.0	40	0.27	10.8	0.74	0.13	0
181	0.71	128.5	1760	94.5	40	0.29	11.6	0.74	0.12	0
40	2.50	100.0	389	71.6	200	0.04	8.0	0.72	0.11	0
79	2.06	162.7	768	135.1	200	0.10	20.0	0.83	0.15	0
129	2.30	296.7	1254	255.7	200	0.11	22.0	0.86	0.09	0
181	1.62	293.2	1760	251.3	200	0.15	30.0	0.86	0.12	0

/015

Submersible Pump Laboratory Trials

Prototype 2. Moyno model 23201 rotor and stator, with 3/8 inch steel shaft coupling.
Stator restrained by fibre reinforced tape

TABLE 4

Doerr DC Motor, 3/4 HP, max 180 volts, max 1750 rpm
Power lost = 3.70 I*I + 0.0041(n)^1.2
in which I amps is current, n rpm is motor speed

Tests of 02 March 1987

INPUT POWER			MOTOR		WATER POWER			EFFICIENCIES		
Volts	Current amps	Power watts	Speed rpm	Power from Motor watts	Press-ure kPa	Flow l/sec	Power from Pump watts	Motor	Pump	Motor & Pump
35.0	0.490	17.2	340	11.8	55	0.039	2.2	0.69	0.18	0.13
61.4	0.462	28.4	597	18.8	55	0.088	4.8	0.66	0.26	0.17
102.5	0.486	49.8	997	32.7	55	0.170	9.4	0.66	0.29	0.19
130.2	0.515	67.1	1266	44.4	55	0.202	11.1	0.66	0.25	0.17
161.0	0.527	84.8	1565	55.9	55	0.318	17.5	0.66	0.31	0.21
34.9	0.683	23.8	339	17.6	100	0.036	3.6	0.74	0.20	0.15
60.7	0.629	38.2	590	28.0	100	0.074	7.4	0.73	0.26	0.19
100.1	0.618	61.9	973	44.6	100	0.154	15.4	0.72	0.34	0.25
130.7	0.620	81.0	1271	57.9	98	0.219	21.5	0.71	0.37	0.26
160.7	0.680	109.3	1562	79.7	98	0.265	26.0	0.73	0.33	0.24
40.1	0.914	36.7	390	28.3	150	0.020	3.0	0.77	0.11	0.08
61.2	0.840	51.4	595	40.0	150	0.070	10.5	0.78	0.26	0.20
102.8	0.834	85.7	999	66.9	155	0.138	21.4	0.78	0.32	0.25
132.0	0.790	104.3	1283	80.0	150	0.177	26.6	0.77	0.33	0.25
160.0	0.818	130.9	1556	100.7	155	0.226	35.0	0.77	0.35	0.27
45.8	1.010	46.3	445	36.3	198	0.009	1.8	0.78	0.05	0.04
60.9	1.000	60.9	592	48.5	198	0.031	6.1	0.80	0.13	0.10
100.3	0.960	96.3	975	77.0	198	0.105	20.8	0.80	0.27	0.22
131.5	0.970	127.6	1278	102.2	200	0.156	31.2	0.80	0.31	0.24
160.0	0.979	156.6	1556	125.4	200	0.231	46.2	0.80	0.37	0.29

N.B. Tape restraining stator failed at head of 270 kPa.
Testing at larger values of head not possible

Submersible Pump Laboratory Trials

TABLE 5

Prototype 2A. Moyno model 23201 rotor and stator, with
3/8 inch steel shaft coupling.
Stator supported by manufacturer's alloy pump cover
Water temperature 16C
Doerr DC Motor, 3/4 HP, max 180 volts, max 1750 rpm
Power lost = 3.70 I*I + 0.0041(n)^1.2
in which I amps is current, n rpm is motor speed

Tests of 21 March 1987

INPUT POWER			MOTOR		WATER POWER			EFFICIENCIES		
Volts	Current amps	Power watts	Speed rpm	Power from Motor watts	Press-ure kPa	Flow l/sec	Power from Pump watts	Motor	Pump	Motor Pum
29.9	0.540	16.1	291	11.4	99	0.028	2.7	0.70	0.24	0.1
45.2	0.530	24.0	439	16.8	99	0.059	5.8	0.70	0.35	0.2
60.6	0.541	32.8	589	23.1	100	0.090	9.0	0.70	0.39	0.2
99.9	0.550	54.9	971	38.1	100	0.158	15.8	0.69	0.42	0.2
130.4	0.536	69.9	1268	47.1	100	0.220	22.0	0.67	0.47	0.3
160.0	0.550	88.0	1556	59.1	98	0.253	24.8	0.67	0.42	0.2
100.9	0.688	69.4	981	51.7	156	0.147	22.9	0.75	0.44	0.3
130.7	0.700	91.5	1271	67.9	156	0.209	32.6	0.74	0.48	0.3
45.0	0.800	36.0	438	27.6	200	0.037	7.4	0.77	0.27	0.2
60.9	0.811	49.4	592	38.3	199	0.055	10.9	0.77	0.29	0.2
100.7	0.806	81.2	979	62.8	198	0.136	26.9	0.77	0.43	0.3
130.9	0.822	107.6	1273	83.3	198	0.191	37.8	0.77	0.45	0.3
160.7	0.834	134.0	1562	103.6	200	0.243	48.6	0.77	0.47	0.3
45.1	1.090	49.2	438	38.7	300	0.030	9.0	0.79	0.23	0.1
60.1	1.090	65.5	584	52.5	300	0.050	15.0	0.80	0.29	0.2
100.4	1.090	109.4	976	89.2	300	0.110	33.0	0.81	0.37	0.3
130.5	1.085	141.6	1269	115.5	300	0.168	50.4	0.82	0.44	0.3
160.0	1.100	176.0	1556	143.8	300	0.199	59.7	0.82	0.42	0.3
45.4	1.320	59.9	441	47.4	400	0.014	5.6	0.79	0.12	0.0
60.0	1.310	78.6	583	63.7	399	0.036	14.2	0.81	0.22	0.1
100.8	1.310	132.0	980	109.8	397	0.091	36.1	0.83	0.33	0.2
130.6	1.320	172.4	1270	144.2	400	0.123	49.2	0.84	0.34	0.2
160.0	1.330	212.8	1556	178.5	400	0.161	64.4	0.84	0.36	0.3
100.3	1.530	153.5	975	129.0	502	0.066	32.9	0.84	0.25	0.2
160.6	1.550	248.9	1561	212.2	497	0.115	57.2	0.85	0.27	0.2

Submersible Pump Laboratory Trials
Prototype 3. Moyno model 33301 rotor and stator, with
3/8 inch steel shaft coupling.
Stator supported by plaster of paris fill.
Water temperature 22C
Doerr DC Motor, 3/4 HP, max 180 volts, max 1750 rpm

TABLE 6

Power lost = 3.70 I*I + 0.0041(n)^1.2
in which I amps is current, n rpm is motor speed

Tests of 16 April 1987

INPUT POWER			MOTOR		WATER POWER			EFFICIENCIES		
Volts	Current amps	Power watts	Speed rpm	Power from Motor watts	Press -ure kPa	Flow l/sec	Power from Pump watts	Motor	Pump	Motor & Pump
60.0	0.79	47.4	583	36.5	94	0.1740	16.4	0.77	0.45	0.35
81.8	0.79	64.6	795	49.9	98	0.2540	24.9	0.77	0.50	0.39
103.0	0.82	84.5	1001	65.6	100	0.2960	29.6	0.78	0.45	0.35
120.7	0.79	95.4	1173	73.3	95	0.3870	36.8	0.77	0.50	0.39
141.0	0.83	117.0	1371	90.6	100	0.4400	44.0	0.77	0.49	0.38
161.0	0.92	148.1	1565	117.0	115	0.5060	58.2	0.79	0.50	0.39
179.0	0.99	177.2	1740	141.8	120	0.5460	65.5	0.80	0.46	0.37
22.1	1.35	29.8	215	20.5	181	0.0420	7.6	0.69	0.37	0.25
39.9	1.30	51.9	388	40.4	185	0.0880	16.3	0.78	0.40	0.31
62.1	1.23	76.2	604	61.7	190	0.1360	25.8	0.81	0.42	0.34
81.2	1.21	98.3	789	80.5	193	0.1880	36.3	0.82	0.45	0.37
101.0	1.21	122.2	982	100.8	195	0.2570	50.1	0.83	0.50	0.41
121.9	1.22	148.7	1185	123.2	199	0.3240	64.5	0.83	0.52	0.43
140.5	1.24	174.2	1366	144.8	200	0.3710	74.2	0.83	0.51	0.43
161.2	1.26	203.1	1567	169.3	205	0.4000	82.0	0.83	0.48	0.40
179.9	1.30	233.9	1749	195.7	205	0.476	97.6	0.84	0.50	0.42
42.3	2.17	91.8	411	68.7	350	0.064	22.4	0.75	0.33	0.24
61.6	2.03	125.0	599	101.0	350	0.108	37.8	0.81	0.37	0.30
81.0	1.96	158.8	788	132.3	350	0.149	52.2	0.83	0.39	0.33
100.5	1.90	191.0	977	161.7	350	0.192	67.2	0.85	0.42	0.35
119.0	1.88	223.7	1157	191.2	350	0.236	82.6	0.85	0.43	0.37
141.5	1.88	266.0	1376	229.0	350	0.298	104.3	0.86	0.46	0.39
160.0	1.85	296.0	1556	255.6	350	0.336	117.6	0.86	0.46	0.40
179.0	1.88	336.5	1740	291.7	350	0.380	133.0	0.87	0.46	0.40
43.3	2.27	98.3	421	73.4	392	0.059	23.1	0.75	0.31	0.24
60.4	2.16	130.5	587	104.6	392	0.102	40.0	0.80	0.38	0.31
80.5	2.13	171.5	783	142.5	408	0.134	54.7	0.83	0.38	0.32
100.0	2.04	204.0	972	172.8	399	0.172	68.6	0.85	0.40	0.34
120.9	2.02	244.2	1175	209.3	400	0.203	81.2	0.86	0.39	0.33
141.5	2.01	284.4	1376	245.5	408	0.247	100.8	0.86	0.41	0.35
161.0	2.00	322.0	1565	279.3	405	0.285	115.4	0.87	0.41	0.36
179.0	1.99	356.2	1740	309.8	403	0.348	140.2	0.87	0.45	0.39
42.0	2.45	102.9	408	75.1	485	0.036	17.5	0.73	0.23	0.17
62.0	2.45	151.9	603	120.8	496	0.072	35.7	0.80	0.30	0.24
82.0	2.36	193.5	797	160.5	493	0.107	52.8	0.83	0.33	0.27
100.0	2.30	230.0	972	194.6	495	0.142	70.3	0.85	0.36	0.31
120.5	2.28	274.1	1172	235.3	495	0.168	83.2	0.86	0.35	0.30
142.5	2.28	324.2	1385	280.9	499	0.208	103.8	0.87	0.37	0.32
160.0	2.28	364.0	1556	317.1	502	0.233	117.0	0.87	0.37	0.32
180.0	2.28	409.5	1750	358.4	507	0.273	138.4	0.88	0.39	0.34

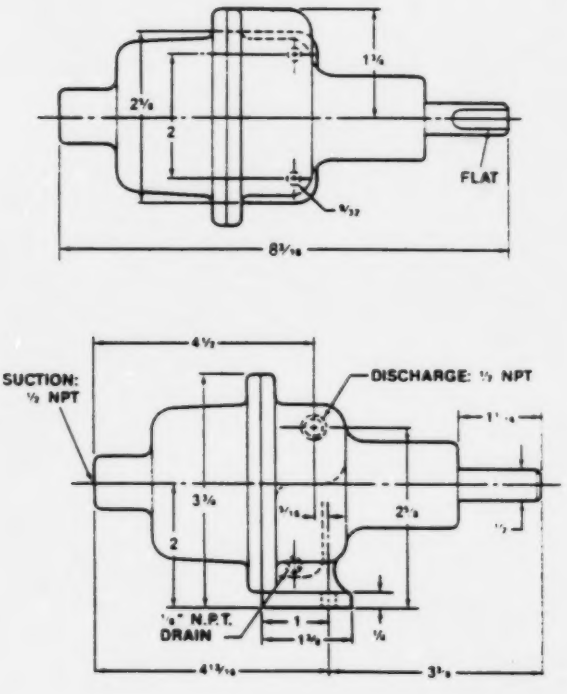
APPENDIX

SPECIFICATION DATA

MOYNO® SP PUMPS

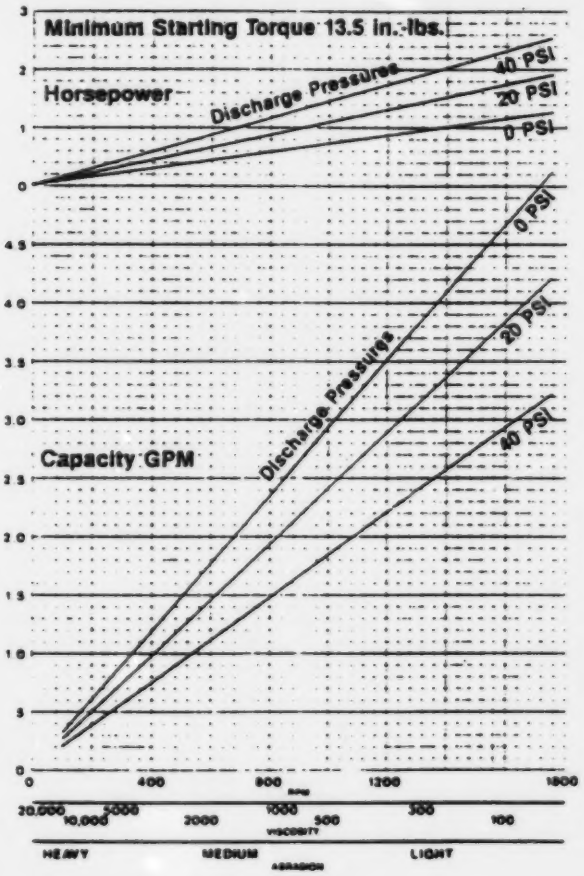
SERIES 232

DIMENSIONS



All dimensions are in inches.
Specifications subject to change without notice.

PERFORMANCE (Water at 70°F)



MATERIALS OF CONSTRUCTION

COMPONENT	MODELS	
	23201	23203
Housing	Aluminum	316 SS
Rotor	416 SS/CP	316 SS/CP
Stator	NBR (Nitrile)	NBR (Nitrile)
Weight (lbs)	3	6

NOTE: For fluids with viscosity over 200 CP (1000 SSU), pump capacity is reduced by 20%.

CP = Chrome plated

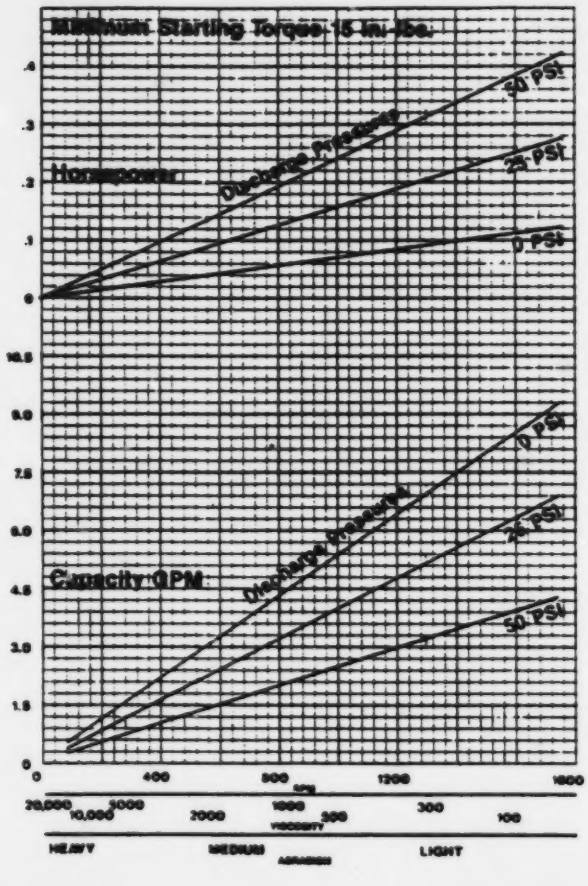
* Moyno is a registered trademark of Robbins & Myers, Inc.

©1984—By Moyno® Industrial Products, Fluids handling Division, Robbins & Myers, Inc.

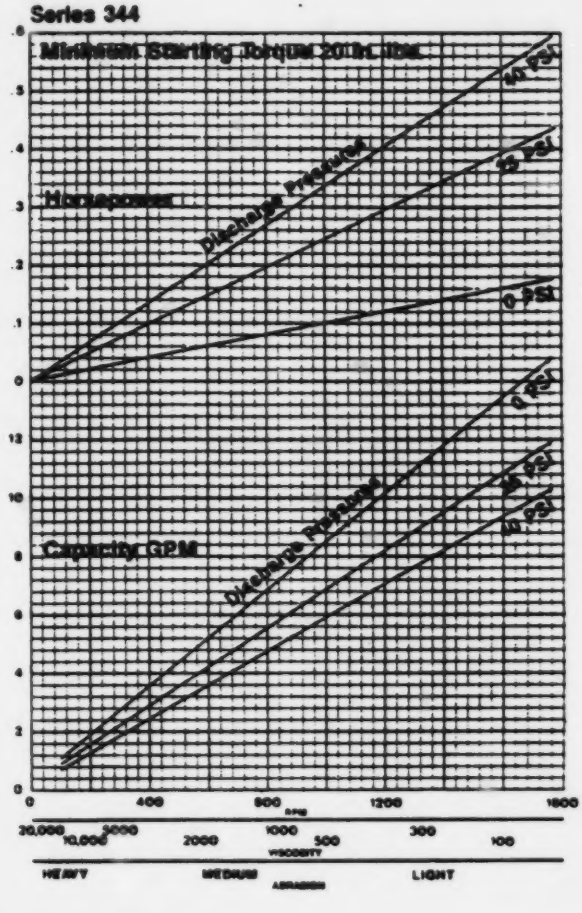
APPENDIX

PERFORMANCE (water at 70°F) (CONT)

Series 333



Series 344



NOTE: For fluids with viscosity over 200 CP (1000 SSU), pump capacity is reduced by 20%.

©1984—By Moyno® Products, Fluids Handling Division, Robbins & Myers, Inc.

Ordering information

APPENDIX

APPENDIX - MANUFACTURER'S INFORMATION
DOERR PERMANENT MAGNET MOTORS

Refer to page 9

SELECTION FORMULA FOR SPEED REDUCERS

REDUCER SIZE	RATIO	STYLE	BASE	ASSEMBLY	TYPE
(Example) 133	30	VM			0
Select size from gearmotor selection charts, page 8.	For speed reducers, select ratio from rating charts, page 8.	Select style from dimension charts, page 9.	0=All horizontal mounts 1=Long base. (vert.) 2=Short base. (vert.)	Looking at input flange 1=Double shaft 2=Left side Shaft 3=Right side Shaft	Use zero for any standard reducer, or number 1 for special requirements.

ELECTRICAL SPECIFICATIONS
SCR Control

HORSEPOWER	⅓	½	¾	1	1½	2	3	5
AC Volts	115	115	115	115/230	115/230	115/230	230	230
AC Amps	2.2	4.5	6	7.9/4.2	10.1/5.5	14.9/7.8	12.0	14.9
AC Fuse Size	2.5	5	6.25	8/5	12/6.25	15/8	12	15
DC Voltage	90	90	90	90/180	90/180	90/180	180	180

ELECTRICAL SPECIFICATIONS
PM Motors

HORSEPOWER	⅓	½	¾	1	1½	2	3	5
RPM (Base Speed)	1725	1725	1725	1725	1725	1725	1800	1800
Torque (Lb-In.)	4.3	8.75	11.6	17.5	26.2	36	54	72
Armature Current (AMPS)	1.45	2.85	3.5	5.35/2.8	8.1/3.5	10.6/5.35	8.2	11.6
Armature Resistance (OHMS)	6.15	3.1	2.3	1.43/5.7	.91/3.26	.62/2.36	1.0	.7
Armature Inductance (MH)	62	35	32	19/79.5	15/60	9/37	18	14
Armature Inertia Lb. In.²	2.2	4.1	5.28	7.92/7.96	11.04/11.1	13.9/14	42.47	46.33
Frame	S56	S56	S56	S56/S56	S56/S56	S56/S56	143T	143T
Duty	CONT.	CONT.	CONT.	CONT.	CONT.	CONT.	CONT.	CONT.
Enclosure	TENV	TENV	TENV	TEFC/TEFC	TEFC/TEFC	TEFC/TEFC	TEFC	TEFC
DC Voltage (Volts)	90	90	90	90/180	90/180	90/180	180	180

See back cover for WARRANTY STATEMENT